

EFFECT OF WEATHERING ON THE GASIFICATION OF ANTHRACITE

Peter L. Rozelle and Alan W. Scaroni

Fuel Science Program
The Pennsylvania State University
Combustion Laboratory
University Park, PA 16802

Background

Recent developments in electric power generation in the northeastern United States have cast a favorable light on anthracite as a power plant fuel. Although it has not received much attention in the literature, anthracite has been used continuously to generate power for over a century. The recent attention being paid to anthracite is largely due to investments being made in anthracite-fired cogeneration plants. (1) This paper presents some of the development work being done to put one such plant into commercial operation. The objective of the investigation was to specify fuel and operating parameters to allow cheap low-grade anthracite reclaimed from refuse to be fired in fixed-bed Wellman Galusha gas producers designed for premium anthracite.

The Pennsylvania anthracite deposits underlay approximately 480 square miles of the eastern part of the Commonwealth of Pennsylvania (see Figure 1). Table I shows variations in the H, O and N concentrations of 46 samples taken from the four major anthracite fields (2) (Northern, Eastern Middle, Western Middle, Southern). Some of the variations listed in Table I were caused by weathering of the coal. This paper reports on how the weathering of anthracite refuse can affect the gasification performance of the fuel derived from it.

Anthracite refuse is the legacy of a century and a half of coal mining in eastern Pennsylvania. It is a mixture of preparation plant refuse, noncarbonaceous mine refuse, wood, cinders, and discarded equipment such as mine cars and boattice cloth. There is low grade coal in these deposits, which can be expediently reclaimed to provide a relatively inexpensive solid fuel. Anthracite refuse has been stored above ground in a broken state and as such its chemical constitution is subject to change due to exposure to the elements. The weathering process can oxidize the organic fraction of coal as well as associated minerals.

Oxidation of lower rank coals due to weathering is a well known phenomenon, but little has been written about anthracite weathering. The organic fraction of the coal is known to lose calorific value upon exposure to the elements. For above ground deposits 5-10 years old, this can be up to 100-200 Btu/lb, while 40-year-old deposits have lost as much as 500 Btu/lb. (3) Refuse-derived anthracite is known to have a high volatile matter content compared to freshly-mined coal, this being due to its high mineral-derived water and chemisorbed oxygen contents.

The pyrite contained in anthracite, which can represent as much as 5% of the coal's mineral matter, is also subject to weathering. Pyrite in refuse banks can be oxidized to iron sulfate and sulfuric acid (4), the latter contributing to groundwater pollution. This is also of interest to fixed-bed gasification, since pyrite is the principal source of iron (in reduced form) in the gasifier bed, which is known to cause severe bed agglomeration and can lead to expensive gasifier downtime.

The focus of this paper is the weathering of the organic fraction of refuse-derived anthracite. While the effect of long-term ambient temperature oxidation of anthracite has not been widely studied, short-term low-temperature (100-350 C) oxidation has been the subject

of investigations (5). The aim of the work was to use mine gas composition to chart the path of underground mine fires, and data have been generated on the effect of low temperature oxidation on the volatile matter content and composition of anthracite. The normal volatile matter of freshly-mined anthracite contains predominantly hydrogen. Table II shows average volatile matter compositions for 46 anthracite samples. The bulk of the volatiles are evolved above 735 C for heating rates between 2 and 16 C/min. CO and H₂ are the principal species liberated above this temperature while CO₂ and CH₄ evolution occurs at lower temperatures.

A fixed-bed Wellmann-Galusha gasifier can be divided into distinct zones along its vertical axis. Upwards from the bottom they are the cinder, burn, gasification, devolatilization, and drying zones (see Figure 2). Devolatilization is the second last process which impacts the composition of the producer gas before it leaves the gasifier. As such, any change in volatile matter quality and/or evolution temperature will affect producer gas quality. Preoxidation, such as that induced by weathering, has been shown by the Bureau of Mines (5) to dramatically affect the content and composition of anthracite volatile matter and lower the evolution temperatures of CO and CO₂. In that work coals were oxidized for relatively short times (generally less than 100 hours) in dry air at temperatures ranging from 100 to 350 C. Increases in oxygen content at lower temperatures, such as 2.2 to 4.1% wt O₂ (dry) in 91 hours at 200 C, correspond to the range of weathering-induced oxidation which although taking place at a lower temperature, occurs over decades rather than hours and as such could produce similar alterations to the volatile matter.

Oxygen interacting with anthracite during low-temperature oxidation was found to produce gaseous products, such as H₂O and CO₂, and to be "fixed" on the coals. The quantity of adsorbed oxygen was found to linearly increase the volatile matter content. Distillation tests on the oxidized coal showed that preoxidation lowered the H₂ and CH₄ yields by 30-50%, while producing order of magnitude increases in CO and CO₂ evolution. It also radically increased the amount of CO being liberated in the 500-900 C range. (5) This is of importance to gasifier operation since the lower the temperature at which a gaseous species is liberated, the closer it is to the gas offtake and this increases its chances of passing out of the gasifier unreacted.

Experimental

Two freshly-mined and four refuse-derived anthracites were sampled for this work (Table III). One sample from other work, sample IIIa, was included since freshly-mined coal from this location is unavailable. Samples Ia and IIa were produced in preparation plants. Sample IIIa was laboratory-prepared. In each case corresponding refuse-derived samples were prepared in an attempt to match the organic fractions as closely as possible. Specific gravity and particle size were the parameters varied to achieve this. Table III lists the specific preparation data on the samples.

Table IV shows the approximate ages of the refuse-derived fuels and Table V gives the ultimate analyses of the fuels. As expected, the data indicate a higher degree of oxidation for refuse-derived fuels than the corresponding freshly-mined coals. While Table V shows a general trend toward higher oxygen contents for refuse-derived coals, a corresponding increase in volatile matter is only present for Sample IIb. Since this fuel, which came from the oldest refuse deposit, indicated the possibility of an increased CO percentage in its volatile matter, it was chosen for full-scale gasification testing. Sample Ia, a freshly-mined low grade coal, was also fired in the Wellman-Galusha gas producers.

Results

Full-scale gasification data for two samples (Ia and IIb) are provided in Table VI, along with published results from two other tests conducted by the Bureau of Mines in the 1950's (6,7). These runs were all conducted in a 10 foot diameter air-blown Wellman-Galusha gas producer. Runs 1 and 2 were conducted in gas producers without bed agitators while 3 and 4 were conducted in the current gas producer, which employs a bed agitator. Run 1 was conducted using freshly-mined premium anthracite and as such can be considered the baseline run for normal operation. Runs 2 and 3 were conducted with low-grade freshly-mined coal and run 4 was conducted with low-grade coal reclaimed from refuse. The higher oxygen and volatile matter contents of sample IIb suggest a high potential yield of CO, and this is reflected in the increase in CO percentage in the producer gas, apparently at the expense of hydrogen. These data are consistent with the previous work on the effect of oxidation on the volatile matter content and composition (5). The results indicate that up to 10% increase in the producer gas calorific value can be achieved by firing refuse-derived anthracite rather than freshly-mined product. Comparisons of the the oxygen and volatile matter contents of refuse-derived and freshly-mined coal from the same location can serve as a measure of the potential to produce this effect. An increase in the (dry-ash-free) oxygen and volatile matter contents indicates a potential increase in the CO content of the producer gas and a corresponding increase in its calorific value.

Summary

Dry-ash-free oxygen contents of several anthracites were compared with published data to determine the extent of oxidation experienced by fuel derived from anthracite refuse. These have been compared to published data on the effect of preoxidation on the composition of the volatile matter in order to predict the effect of weathering on producer gas composition. Full scale gasification data from Wellman-Galusha gasifiers show that a refuse-derived anthracite, which was the oldest and most oxidized fuel, produced a gas enriched in CO. The data imply that refuse-derived anthracites can produce a higher calorific value product gas than freshly-mined coals of similar quality.

References

1. Anon, *Coal and Syntuels Technology*, 28 October, 1985, pp 2-3.
2. Anon., "Physical and Chemical Properties of Pennsylvania Anthracite," Anthracite Institute, Wilkes-Barre, Pa., 1945, 26 PP.
3. Sisler, J. D., T. Fraser, and D. C. Ashmead, *Anthracite Culm and Silt*, PA Bureau of Publication, Bull. M-12, 1928, 268 pp.
4. McCartney, J. C., and R. H. Whaite, *Pennsylvania Anthracite Refuse, A Survey of Solid Waste from Mining and Preparation*, Bu Mines Inf. Circ. 8409, 1969, 77 pp.
5. Scott, G. S., G. W. Jones, and H. M. Cooper, "The Effect of Oxidation on the Volatile Matter of Anthracite and its Significance in Mine Fire Investigations," Bureau of Mines Report of Inv. 3398, May 1938, 8 pp.
6. Eckerd, J. W., J.D. Clendenin, and W.S. Sanner, and R. E. Morgan, "Gasification of Bone Anthracite," Bureau of Mines Rept. of Inv. 5594, 1960, 24 pp..
7. Teure, R. F. J. D. Clendenin, and W. S. Sanner, "Anthracite Gas Producer Tests at a Brick Plant," Bu Mines Rept. of Inv. 5556, 1960, 25 pp.
8. Bracy, G. A., and H. H. Griffiths, *Properties of Anthracite from the Bottom Ross Bed*, Bu Mines Rept. of Inv. 7086, 1968, 29 pp.
9. Reproduced from Wellman Engineering Company brochure.

Table I*. H, O and N Concentrations for Samples from Different Anthracite Fields

Field	No. of Samples	Range of Concentration, wt% dry		
		H	O	N
Northern	22	2.0-3.1	1.1-3.2	0.6-1.1
Eastern Middle	6	1.7-2.0	1.2-1.9	0.6-0.9
Western Middle	6	1.2-2.9	0.9-2.0	0.6-1.0
Southern	12	1.8-3.1	1.1-2.4	0.6-1.2

*From Reference 2

Table II. Average Volatile Matter Composition for Samples from Different Anthracite Fields

Field	No. of Samples	Average Volatile Matter Composition, %vol (dry)					
		CO ₂	O ₂	H ₂	N ₂	CO	CH ₄
Northern	22	1.8	1.0	85.2	1.8	4.1	6.0
Eastern Middle	6	1.9	2.6	81.1	6.9	5.5	1.9
Western Middle	6	1.8	3.3	78.8	7.4	4.5	4.1
Southern	12	2.1	1.2	83.3	3.8	4.0	5.6

TABLE III. SAMPLES USED AND PREPARATION METHOD

Sample	Location	Particle Size Range, mm	Preparation Method
Ia (freshly-mined)	Eastern	14 x 4.7	Prep. Plant, 1.90 float
Ib (refuse-derived)	Middle Field	12.7 x 6.4	Laboratory, 1.90 float
IIa (freshly-mined)	Southern	4.7 x 2.4	Prep. Plant, 1.70 float
IIb (refuse-derived)	Field	4.7 x 1.2	Laboratory, 1.70 float
IIIa* (freshly-mined)	Northern	75 x 0.5	Laboratory, 1.70 float
IIIb (refuse-derived)	Field	50 x 0.5	Prep. Plant, 1.70 float
IVb (refuse-derived)	Western Middle Field	9.5 x 3.2	Laboratory, 1.70 float

*From Reference 8

TABLE IV. ESTIMATED AGE OF REFUSE-DERIVED COALS

Sample	Estimated Age, Yrs
Ib	> 50
IIb	> 40
IIIb	40-80
IVb	> 30

TABLE V. VOLATILE MATTER CONTENT AND ULTIMATE ANALYSIS OF FUELS

SAMPLE	VM	S	C (wt% daf)	H	O	N
Ia	7.8	0.56	95.6	1.47	1.67	0.70
Ib	6.5	0.61	92.8	1.97	3.75	0.87
IIa	6.4	0.93	94.9	1.76	1.78	0.83
IIb	7.3	0.63	93.6	1.59	3.23	0.95
IIIa*	4.4	0.60	94.0	2.30	2.00	1.00
IIIb	8.7	1.27	90.9	1.99	3.87	0.95
IVb	8.6	0.62	93.0	2.12	3.20	0.96

*from Reference 8

TABLE VI. WELLMAN-GALUSHA PRODUCER GAS COMPOSITIONS FROM
PAST AND PRESENT WORK USING ANTHRACITE COAL

Run	Coal Type	Ash Approx. %wt	Dry Producer Gas (% vol)*				CH ₄	CO ₂	Net CV Btu/ft ³	Ref
			H ₂	N ₂	CO					
1	Freshly-Mined	10	18.1	47.6	27.2		1.0	5.9	145	7
2.	Freshly- Mined** Middling	30-45	15.8	51.9	22.6		0.8	8.5	123	6
3	Sample Ia	25-30	17.8	47.3	28.3		0.5	6.0	145	this work
4.	Sample IIb	30-40	15.4	45.0	31.4		0.3	4.2	147	this work
	Gasifier Conditions		-16.3	-47.6	-34.1		-0.4	-4.0	-159	
			Coal feed rate, tons/hr				Saturation Temp. °F			
			1. 1.0 - 2.5				147			
			2. 1.0 - 2.5				170			
			3. 1.0- 1.5				150-160			
			4. 1.0- 1.5				150-160			

*Ranges given for 6 gas samples taken over a 6 hr period

**0.4% O₂ in gas

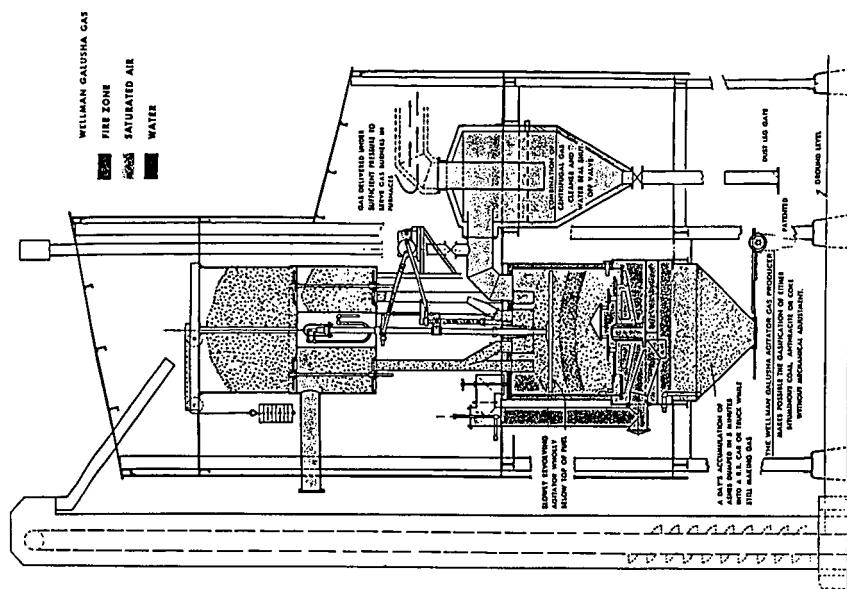
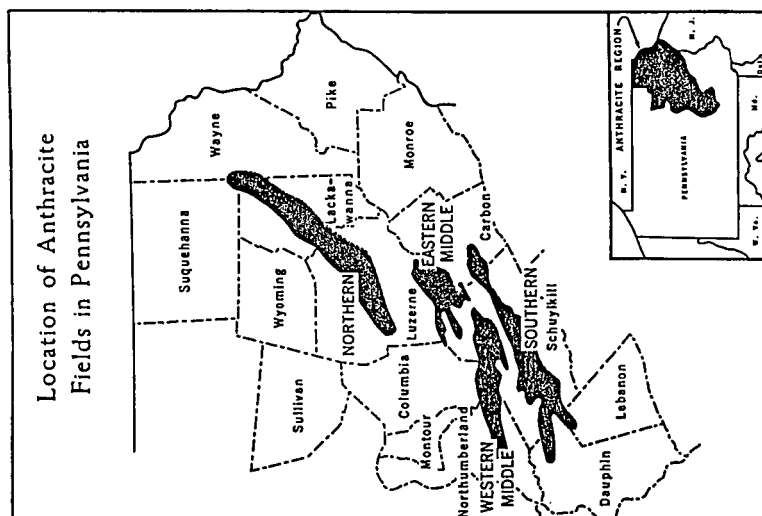


Figure 2. Wellman Galusha Gasifier (9)